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Nominal Feedback Rules for Monetary Policy

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We assess empirically how a particular set of monetary policy rules (suggested by Bennett McCallum) would operate in the transition to zero inflation, and in maintaining price stability thereafter. We do this through repeated stochastic simulations of price and nominal income rules within three different models of the economy. The price rule leads to instability in some models. However, the nominal income rule consistently works with high probability to reduce inflation from present levels to zero in five years, without significantly raising the probability of a recession. That rule also would ensure price stability in the long run, but possibly at the expense of slightly more volatility in real GNP.

It now is widely accepted both outside and inside the Federal Reserve that price stability is the appropriate long-term goal of U.S. monetary policy. This view has been advocated by a substantial part of the economics profession for a long time. The issue recently became the subject of Congressional debate when Representative Stephen Neal proposed that the Congress instruct the Federal Reserve to adopt policies to lower the inflation rate to zero within five years, and to maintain constant prices thereafter.[1] This proposal was endorsed by Federal Reserve Chairman Greenspan and a number of Federal Reserve Bank Presidents (Greenspan 1989, Hoskins 1989, and Parry 1990).

Despite the consensus on price stability as the main long-term goal of monetary policy, the stabilization of real economic activity remains an important short-term goal for most central banks. The desire to achieve both of these goals inevitably raises the issue of which should take precedence at any particular point in time. Most economists would agree that monetary policy tends to have an inflationary bias unless some institutional structure is in place to ensure that the monetary authority achieves its long-term goal of price stability. This consideration raises the long-standing issue of rules versus discretion in the conduct of monetary policy.[2] Proponents of monetary rules argue that unless the monetary authority is required to achieve prescribed values of a nominal variable under its control (such as a monetary aggregate or the monetary base), long-run price stability goals inevitably will be sacrificed for short-run income stabilization objectives. The main argument against rules, and in favor of discretion, however, stems from the belief that following a rule would increase short- to intermediate-term volatility in output, which is considered undesirable.

With the possible exception of three years in the early 1980s, the Federal Reserve has employed a highly discretionary approach in conducting policy. Since the move away from the monetary targeting procedures used from 1979 to 1982, Federal Reserve policy actions have responded to a wide range of economic indicators, including inflation, economic activity, the exchange rate, interest rates, money, and other financial variables (Heller 1988). Even though the Fed still establishes annual ranges for two monetary aggregates (M2 and M3) and a credit aggregate (total nonfinancial debt), these ranges are not consistently binding on its day-to-day operations. Thus, the process of formulating and executing monetary policy in the U.S. currently lacks an explicit nominal target that ensures that discretionary policy actions taken in response to short-run developments do not take aggregate demand off course in the long-run.

In this paper, we review the theoretical arguments for adopting rules for policy, and assess empirically how a particular set of rules would operate both in the transition to zero inflation and in the longer run after that transition has been completed. The rules we examine are feedback rules of the type proposed by Bennett McCallum (1988a, 1988b), in which the central bank adjusts the growth rate of the monetary base in response to observed deviations of the level of nominal income (or some alternative nominal variable) from established target values. In order to assess the risks of adopting different rules, we use numerous stochastic simulations to determine the range of outcomes for real GNP and prices that we could expect if these rules were implemented and the economy experienced shocks similar in magnitude to those in the past. Finally, we use simulations of three different economic models to reflect the alternative paradigms that currently have significant followings among macroeconomists (as discussed in Mankiw 1990). Given the intense theoretical debate going on in the macroeconomics profession, a rule should not be given serious consideration unless it is robust across alternative theories.

The remainder of the paper is organized as follows. Section I presents a brief overview of the literature on the theoretical basis for monetary-policy rules, and the advantages and disadvantages of alternative target variables. Section II discusses the nature of, and rationale for, McCallum's nominal feedback rules. Section III presents the empirical results. The conclusions we draw from these simulations are presented in Section IV.

I. The Role of Monetary Policy Rules

The basic argument in favor of rules in the conduct of monetary policy is that discretion leads to time-inconsistent results. Even if the monetary authority has the same objective function as the general public and acts to maximize that function at every point in time, the results of its actions will be suboptimal in the long-run. The central bank will produce more inflation (but no more real growth) ex post than was desired ex ante (see Barro 1986, Barro and Gordon 1983, and Kydland and Prescott 1977). This result holds even if the central bank maximizes an objective function that assigns negative weight to inflation while putting positive weight on output above its full-employment level.

The key assumptions underlying this result are that there is a positive relation between monetary policy surprises and deviations of output from its full-employment level, and that the public's expectations eventually are consistent with the policy followed by the central bank. Thus, the public can be "fooled" only temporarily. The assumption that the public cannot be fooled permanently means that output cannot deviate from its full-employment level in the long-run, and therefore, that social welfare is maximized by producing zero inflation. Under these circumstances, therefore, if the monetary authority were to adopt a long-run policy rule, it would choose one that produced zero inflation.

At any point in time, however, the monetary authority takes the public's prevailing inflation expectation as a datum. Thus, if it is not bound by a rule, the monetary authority can add to social welfare in the short-run by generating a policy surprise that raises output above its full-employment level. But in the long-run, the authority is unable to raise utility by producing surprises because on average, real GNP cannot be raised above its full-employment level.[3] Indeed, since the average rate of inflation is raised by the authority's discretionary actions, social welfare is actually reduced by the discretionary approach compared with the situation in which a rule is imposed. The extent of the inflationary bias in discretionary policy is affected by the central bank's rate of time preference. The more weight it places on near-term, relative to more distant, developments, the larger is the inflationary bias.

If it is to solve the time-inconsistency problem, a rule must commit the monetary authority permanently and in advance. This would ensure that the public would believe that the rule would be followed into the indefinite future and would form its expectations accordingly. The rule must be stated in terms that the monetary authority is capable of achieving, since otherwise the policymaker cannot be held accountable. For this reason, proposals have been made to require the central bank to stabilize the growth rate of some easily observed and measured variable that is under its direct control, such as the monetary base or the narrow money stock. Friedman's (1960) constant-money-growth rule was an early example of a time-consistent policy commitment.

Contingent rules, so long as they can be clearly defined and enforced, also could solve the time-inconsistency problem. For example, in principle, a time-consistent nominal rule that also specifies how the growth of the monetary base temporarily would respond to business cycles might reduce short-run swings in the economy while at the same time ensuring that money growth would be noninflationary over time. However, it may be difficult to enforce contingent rules, since the monetary authority may be tempted to "cheat" on its longer-run price stability condition in the expectation that the public will be unable to distinguish between cheating and allowable responses to changes in cyclical conditions. Thus it is especially important that contingent rules be specified in terms of an easily observable variable that clearly is under the control of the central bank.

Alternative Nominal Targets

Most analyses of monetary policy rules have begun with the presumption that the target should be money, especially M1. The narrow money supply is appealing because it can be controlled reasonably well by the central bank and because all credible theoretical models view money growth as the unique causal factor in steady-state inflation. However, uncertainties about movements in the velocity of money in the short to intermediate run, related to the deregulation of the financial system, have been a central feature of the U.S. economy and monetary policy since the early 1980s (Simpson 1984). These developments have raised serious doubts about the practical usefulness of money as a target of monetary policy.

These concerns about instability in velocity have motivated proposals that the Fed should target nominal GNP. Thus, this variable has been seen as a second-best solution to the velocity problem (Hall 1983 and Tobin 1980). Targeting nominal GNP would get around the problem of velocity instability, since the money supply automatically would accommodate shifts in velocity under this approach.[4]

The following identity illustrates how nominal income targeting can be used to achieve price level objectives:

$$p_t \equiv x_t - y_t,$$

where p = log of price level
x = log of nominal income
y = log of real GNP

As this identity shows, a predictable relationship between nominal income and the price level depends upon the predictability of the level of real GNP. According to some analyses, the level of real GNP has a long-run trend, called potential GNP, which is determined by long-run supply conditions in the economy, including labor force growth and trend productivity (Evans 1989). Under this hypothesis, these factors evolve gradually over time, and thus trend GNP growth should be relatively easy to predict; that is, it is "trend-stationary." To the extent that this is the case, it is straightforward to calculate the path of nominal GNP required to achieve long-run price stability.

However, Haraf (1986) cites evidence that real GNP is a nontrend-stationary time series. If this were the case, and nominal GNP grew at a constant rate, the price level would evolve as a random walk, and thus could drift over time. This problem would arise if real GNP were affected by supply shocks that had permanent effects on the level of real GNP. As can be seen in the above identity, under nominal income targeting, a positive (negative) supply shock, which brings about a permanent increase (decrease) in output, will induce an unnecessary price level decline (increase). Such responses can be detrimental to macroeconomic performance by raising uncertainty about the level of prices in both the short and long run. Unfortunately, statistical tests are not capable of distinguishing accurately between random walks and trend-stationary processes with autoregressive roots close to unity (Mankiw 1989). Thus, there is some inherent uncertainty concerning possible problems caused by the behavior of real GNP for nominal income targeting.

In part because of this concern, a number of authors have argued that the Federal Reserve should target prices directly (Barro 1986 and Meltzer 1984), since under this approach the price level would not be affected by the time-series properties of real GNP. No matter what time-series properties real GNP displays, direct price level targeting obviously could avoid long-term price level drift. The major potential disadvantage of price level targeting is that in sticky price (Keynesian) models, attempts by monetary authorities to achieve a predetermined path for prices involve very sharp movements in real GNP in the short run, which may not be desirable (Hall 1983). Essentially, if prices are sticky, policy actions have their largest effects on output in the short run. Of course, in flexible price (real business cycle) models this would not be a problem because prices would be able to adjust to policy changes in the short run, requiring no adjustment of output.

Concerns about volatility in real GNP motivate the so-called modified nominal income target proposed by Taylor

(1985), which is defined as the inflation rate plus the GNP "gap" (the difference between real GNP and its full employment level). This target differs from the others discussed above in that it uses the inflation *rate* rather than a nominal *level*. Thus it does not prevent the price level from drifting upward or downward in the long run. For example, if the inflation rate were to rise, the modified nominal income target would call for a tightening of policy only until the inflation rate returned to zero, whereas the nominal income and price targets would require a longer period of tightening until the previous price level was restored. However, modified nominal income may have an advantage over the two other targets discussed above in terms of real GNP volatility. Taylor (1985) shows that, in the context of a rational expectations Phillips curve model, the rule would cause less volatility of real GNP than would a nominal GNP rule.

II. McCallum-Type Rules

The preceding discussion makes it clear that the choice of a nominal target variable cannot be determined from theory alone. This choice depends on such factors as the time series properties of real GNP and the degree of flexibility of prices. An empirical investigation is needed. McCallum (1988a, 1988b) has examined the empirical properties of *operational versions* of nominal income and price rules. These rules specify a long-run equilibrium growth rate for the monetary base plus a rule for adjusting quarterly growth in the base in response to deviations between the actual and desired values of the target variable. They may be written in the form:

$$(1) \quad \Delta b_t = [\Delta p_t^* + \Delta y_t^f] - \Delta \bar{v}_t + \lambda [z_{t-1}^* - z_{t-1}]$$

where b_t = log of the monetary base, p_t = log of price level, y = log of real GNP, z_t = log of target variable, * denotes a value desired by the central bank, and

$$\Delta \bar{v}_t = \left(\frac{1}{16}\right)[(x_{t-1} - b_{t-1}) - (x_{t-17} - b_{t-17})].$$

The left side of (1) represents the growth rate of the monetary base, which serves as the policy instrument. The right side has three components. The first term represents the growth rate of nominal GNP the central bank wishes to accommodate in the long run, which is equal to the sum of the desired inflation rate (Δp^*) and the steady-state growth rate of real GNP (Δy_t^f). The second component, $\Delta \bar{v}$, subtracts the growth rate of base velocity over the previous four years, and is designed to pick up long-run trends in the relation of base growth to nominal GNP growth.[5] The third term specifies the feedback rule determining how base growth is adjusted when there is a target miss in the previous quarter. That miss is defined as $[z_{t-1}^* - z_{t-1}]$, while the term λ defines the proportion of the miss the central bank attempts to offset each quarter. As such, values of λ can be chosen by the central bank between 0 and 1. In steady-state, the feedback term drops out (since $z^* = z$), and the rule simply states that $\Delta b_t = \Delta p_t^* + \Delta y_t^f - \Delta \bar{v}_t$.

McCallum's rules use the monetary base as the operating instrument on the grounds that it can be accurately controlled by the central bank on a day-to-day basis, and that this controllability is unlikely to be upset by financial or regulatory innovations. Thus, when the base is used as the policy instrument, the public can easily observe whether the central bank is adhering to its rule and can hold the central bank accountable for its actions. This feature has the advantage that it provides an opportunity for the central bank to develop credibility with the public. Such credibility may substantially lower the costs, in terms of lost economic output, of reducing inflation (see Blackburn and Christensen 1989).

A drawback to using the base as an instrument is that its velocity has tended to be unstable following the deregulation of the financial system in the 1980s. However, two features of the rules under investigation tend to mitigate the adverse effects of instability in velocity. First, the $\Delta \bar{v}_t$ term accounts for gradual movements in the relationship between base growth and macroeconomic developments. Second, under McCallum-type rules, shifts in the base velocity are automatically offset by policy. For example, if base velocity unexpectedly rises, nominal income will rise relative to the target, which will induce a contraction in the base growth rate under the McCallum rule. This contraction will tend to bring nominal income back to its target.

One of McCallum's main objectives is to test the robustness of the nominal income rule across alternative economic theories, which have different implications for the correlations among Δb, Δp, and Δy in the presence of shocks. He argues that neither theory nor evidence points convincingly to any one of the competing models of the dynamic interaction between nominal and real variables. Because of this uncertainty about the true structure of the economy, the monetary authority should adopt a rule that is likely to work well in a variety of different economic environments. McCallum tests his proposed rule by conducting counterfactual simulations under several alternative macroeconomic models. The rule is designed to be model-free: that is, the monetary authority responds to *observed* deviations from the target, and does not need to base its actions on forecasts or judgments that would require knowledge of the structure of the economy. McCallum's empirical results suggest that if the Fed had followed the rule from 1954 to 1985, there would have been less cyclical variability in nominal GNP and essentially zero inflation, and that this conclusion holds true for all of the models tested.

McCallum, of course, recognizes that these results are subject to the Lucas (1973) critique: the estimated parameters in the models he estimates and simulates might have changed significantly if the Federal Reserve actually had followed the rules being tested. McCallum (1988a) attempts to deal with this issue in two ways. First, he cites Taylor's (1984) finding of parameter stability across the Fed's policy regime change in 1979, and argues that the Lucas critique may not be empirically important in the context of monetary policy rules. Second, he substantially alters the coefficients in one of his estimated models, and shows that the simulation results are qualitatively unchanged (McCallum 1988a, pp. 192–194).

Extensions of McCallum's Exercise

We extend McCallum's results in a number of directions. First, we consider another target variable in addition to nominal GNP and the price level, namely, Taylor's modified nominal income rule. Thus, three alternative short-run target variables for the policy rules are considered: nominal income (equation 2), the price level (equation 3) and modified nominal income (equation 4). In addition, "no rule" simulations also are computed, in which the monetary base followed the same path as in the historical sample period:

$$(2)\quad \Delta b_t = [\Delta y_t^f + \Delta p_t^*] - \Delta\bar{v}_t + \lambda[x_{t-1}^* - x_{t-1}]$$

$$(3)\quad \Delta b_t = [\Delta y_t^f + \Delta p_t^*] - \Delta\bar{v}_t + \lambda[p_{t-1}^* - p_{t-1}]$$

$$(4)\quad \Delta b_t = [\Delta y_t^f + \Delta p_t^*] - \Delta\bar{v}_t + \lambda[(y_{t-1}^f - y_{t-1}) + (\Delta p_{t-1}^* - \Delta p_{t-1})].$$

Second, we conduct repeated stochastic counterfactual simulations of the alternative models and rules. In McCallum's simulations, the monetary authority is assumed to face the same set of shocks that actually occurred in the historical period. Below, we assume only that the shocks have the same means and variances as the historical shocks. Thus, rather than computing a single simulation of the economy under each rule, we obtain a probability distribution of alternative outcomes based upon numerous sets of shocks. This enables us to compare different rules in terms of the full range of alternative outcomes that each might produce. Third, we examine how adoption of various rules might affect the volatility of real GNP. Since concerns about such effects seem to be a major reason that many central banks hesitate to adopt rules, we focus a good deal of our attention on this issue. Finally, we examine how alternative rules might be used to bring the inflation rate down from its level in recent years to zero over the five-year horizon specified in the Neal Amendment.

III. Empirical Results

Each of the policy rules was simulated under three alternative sets of assumptions about the structure of the economy: a Keynesian (or Phillips curve) model, a real business cycle model, and an atheoretic vector autoregression (VAR).[6] We closely followed McCallum in specifying and estimating these models, and our estimates are close to those reported by McCallum (1988b). As will become apparent, the models are not attempts to describe the structure of the economy as precisely as possible. Rather, they incorporate the fundamental features of the various macroeconomic paradigms, and are meant to illustrate the basic nature of the responses of the economy to the implementation of the monetary-policy rules tested.

The Keynesian model consists of three equations. First, the real aggregate demand equation embodies the direct effects of monetary (and fiscal) policy on macroeconomic activity. It specifies the growth rate of real GNP as a function of current and lagged growth rates of the real monetary base, real government spending (g), and its own lagged values (our estimates of the parameters of this aggregate demand relation are shown in equation A1 of the Appendix):

$$(5)\quad \Delta y_t = \sum_{i=1}^{I} \alpha_i \Delta y_{t-i} + \sum_{j=0}^{J} \beta_j (\Delta b_{t-j} - \Delta p_{t-j}) + \sum_{k=0}^{K} \gamma_k \Delta g_{t-k}.$$

The supply side of the Keynesian model is a simplified Phillips curve, which embodies the essential "sticky-price" characteristic of the paradigm. It specifies that the current inflation rate depends on past inflation and the gap between actual and full employment real GNP (see equation A2 of the Appendix):

$$(6)\quad \Delta p_i = \sum_{n=0}^{N} h_n (y_{t-n} - y^f_{t-n}) + \sum_{m=1}^{M} k_m \Delta p_{t-m},$$

where

$$\sum_{m=1}^{M} k_m = 1.$$

The coefficients on lagged inflation (k_m) are constrained to sum to 1, thus ensuring that, in steady state, real GNP will be equal to its full employment level, and inflation will be constant. Equation (7) defines y^f, which is the log of full employment real GNP and is measured as the fitted values of a log linear time trend (T) of real GNP (see equation A3 in the Appendix):

$$(7)\qquad y^f_t = \delta + \zeta T_t.$$

In combination with any one of the policy rules that defines the growth rate of the base, equations (5), (6), and (7) can be simultaneously solved for values of Δp, Δy, y^f, and Δb as functions of the monetary policy target and other variables. For the purpose of evaluating monetary policy rules, the essential feature of this model is that monetary policy affects real GNP with relatively short lags, while inflation is affected with long lags. This means that attempts to exert precise control over inflation in the short run inevitably involve a high degree of volatility of real GNP. As noted above, it is this concern that has motivated the view that nominal GNP or modified nominal GNP might be a better target variable, since neither requires such precise short-run control of the price level.

The real business cycle model consists of two equations. First, the price determination equation is obtained by inverting equation (5) (see equation A4 in the Appendix):

$$(8)\quad \Delta p_t = \left(\frac{-1}{\beta_0}\right) \Delta y_t + \sum_{i=1}^{I} \left(\frac{\alpha_i}{\beta_0}\right) \Delta y_{t-i} + \Delta b_t + \sum_{j=1}^{J} \left(\frac{\beta_j}{\beta_0}\right) (\Delta b_{t-j} - \Delta p_{t-j}) + \sum_{k=0}^{K} \left(\frac{\gamma_k}{\beta_0}\right) \Delta g_{t-k}.$$

This specification of the price equation follows from the assumption that prices are flexible and that real GNP is independent of aggregate demand. Thus inflation is directly determined by current and lagged values of monetary base growth, real GNP growth, and other variables.

Real GNP is determined by a simple time series model, which is consistent with movements in real GNP being determined by *permanent* technology and labor supply shocks. Thus equation (9) specifies that real GNP has a unit root (that is, shocks have a permanent effect on the level of real GNP; see equation A5 in the Appendix for econometric estimates):

$$(9)\qquad \Delta y_t = \theta + \sum_{l=1}^{L} \mu_l \Delta y_{t-l}.$$

Any of the monetary policy rule equations and equations (8) and (9) can be solved for values of Δp, Δy, and Δb as functions of values of the monetary policy target and other variables. For present purposes, the key features of this model are that prices respond immediately to changes in the base and real GNP is unaffected by monetary policy. Thus, short-run control of prices is much more appealing than in the Keynesian model. Furthermore, the distinction between controlling prices and nominal income is nonexistent, since real GNP does not respond to monetary policy.

Thus the Keynesian and real business cycle models make opposite assumptions about the responsiveness of prices and real GNP to monetary policy actions. The Keynesian model assumes that real GNP responds relatively quickly but that prices lag; the real business cycle model, however, assumes that prices respond quickly but that real GNP does not respond at all. By testing the various rules in both models, we have encompassed the broad range of assumptions that potentially could be made in this regard.

In addition to the two models just discussed, we also conducted simulations using a four-variable VAR that included growth rates of nominal GNP, the price level, and the base, as well as the level of the Treasury bill rate (see Appendix A for estimation results). In simulating this model under a policy rule, the estimated equation for the base was replaced by the equation defining the policy rule. The VAR embodies no theoretical restrictions, and therefore is agnostic about the structure of the economy.

Simulating the Models

Two basic questions were addressed with dynamic simulations of the estimated models. First, how would the principal macroeconomic variables (real and nominal GNP, prices and the inflation rate) have evolved over the historical sample period (1954 to 1989) if the monetary authority had followed each of the three policy rules throughout that period? We label these simulations as "counterfactual experiments." The policy rules in these simulations were specified to attempt to hold the price level constant at its level in 1954. For each rule, within the context of each model, we calculated 500 simulations in which the shocks had the same variances as the error terms in the respective model equations.[7] Each set of 500 simulations is called an experiment. We calculated a 95 percent confidence interval for each of these experiments.

Second, how might the economy evolve in the future if the monetary authority adopted a policy rule beginning in 1990 with the objective of lowering inflation gradually to zero by 1995 and holding the price level constant thereafter? For these disinflation experiments, we assumed that the shocks to aggregate demand and aggregate supply in the future would have the same variances as in the estimation sample period. Again, we calculated confidence intervals based upon 500 simulations for each experiment.

Counterfactual Experiments

In presenting the results from simulating the alternative rules, we focus on three measures of economic performance that should reflect the concerns of policymakers—the price level, the rate of inflation and the short-run growth rate of real GNP. Ideally, a policy rule should deliver low inflation, in both the short run and long run, without causing unacceptable volatility in real GNP growth. Given the conventional definition of a recession as two quarters of declining GNP, we focus on the (annualized) two-quarter growth rate of real GNP.

Table 1 shows the performance of the various rules in stabilizing the price level by reporting the 95 percent confidence intervals for average annual inflation over 1954.Q1 to 1989.Q4. With some notable exceptions discussed below, adoption of the rules could have stabilized prices in the long run. In most cases, the confidence bands center around an average inflation rate near zero.[8] Moreover, these confidence bands are in most cases much narrower under the rules than under the policy actually followed over the period (the "no rule" case). For example, in the Keynesian model with $\lambda = 0.25$, average inflation would have been between -0.67 and $+0.48$ percent (with 95 percent probability) under a nominal income rule, but between 2.60 and 5.89 percent with no rule. Only the modified nominal income rule under the real business cycle model produced confidence bands wider than the no rule case. This result confirms our speculation that this rule would allow the price level to drift in the long run because it targets the short-run inflation rate rather than the price level. Price level drift is especially acute in the real business cycle model because of its unit root in real GNP.

Several of the experiments summarized in Table 1 produced explosive cycles in the economy. In particular, although the price rule works well in the real business cycle

Table 1

Simulated Inflation Rate Under Alternative Rules[a]

1954-1989

		95% Confidence Limits[b]		
Policy Rules		Keynesian	Real Business Cycle	Vector Autoregression
Nominal GNP	$\lambda = 0.25$	−0.67 to 0.48	−0.58 to 0.75	−2.26 to −0.31
	$\lambda = 0.50$	−0.47 to 0.33	−0.61 to 0.78	−2.23 to −0.38
	$\lambda = 0.75$	−0.40 to 0.28	−0.64 to 0.80	Explosive
Price Level	$\lambda = 0.25$	Explosive	0.002 to 0.14	−0.31 to 0.27
	$\lambda = 0.75$	Explosive	0.02 to 0.18	−0.32 to 0.45
Modified Nominal GNP	$\lambda = 0.25$	−1.43 to 1.75	−15.2 to 17.0	Explosive
	$\lambda = 0.75$	−0.96 to 1.13	−30.7 to 33.4	Explosive
No Rule (Actual Base)		2.60 to 5.89	2.78 to 6.31	3.16 to 5.77
Actual Inflation			4.43	

[a]These results are referred to as counterfactual experiments in the text.
[b]Annual rates of change.

model with its flexible prices, it produces instability in the "sticky price" Keynesian model. The modified nominal income rule works well in the Keynesian (Phillips curve) context, for which it was designed, but causes instability in the VAR.[9] In fact, only the nominal income rule with cautious policy responses (λ = 0.25 and 0.50) was stable in all three models.

Thus the results of these simulations show that the nominal income rule is more robust across alternative models than are the price and modified nominal income rules. Within the context of uncertainty about the true structure of the economy, the nominal income rule is the only one tested that is not explosive in any of the macro models (for suitably small values of λ) and so could be considered a viable approach for policy. To illustrate the effects of this rule (with λ = 0.25), in Chart 1 we have plotted the 95 percent confidence intervals for the price level. In all of the models, the confidence intervals center throughout the simulation period on a price level near its level at the beginning of the period, and the confidence bands are relatively narrow. For comparison, the 95 percent confidence interval for the no-rule simulations, with the monetary base taking on its actual historical values, also are plotted. These results suggest that by following the nominal income rule, monetary policy could have avoided the inflation that occurred over this period with high probability.

As noted in the introduction, one reason often given by central banks for not taking advantage of rules to control inflation is that nondiscretionary approaches tend to create volatility in real GNP. To address this issue, Table 2 reports the 95 percent confidence intervals for the two-quarter growth rate of real GNP *for the year 1989*, under the rules in the three models and for the no rule case. Since the width of the confidence intervals varies somewhat over the simulation period, we show the results for 1989 as a representative year. In evaluating these results, we use the no rule case as a basis for comparison, since it is an estimate of the confidence band that actually obtained over the sample period under the policies followed by the Fed. Of course, the rules have no effect on real GNP in the real business cycle model. In most other cases, the bands are wider under the rules than in the no rule case, implying that rules-based regimes may increase the short-run volatility of real

Chart 1
Simulated Price Level
Nominal GNP Rule
Versus No Rule
(95% Confidence Intervals)

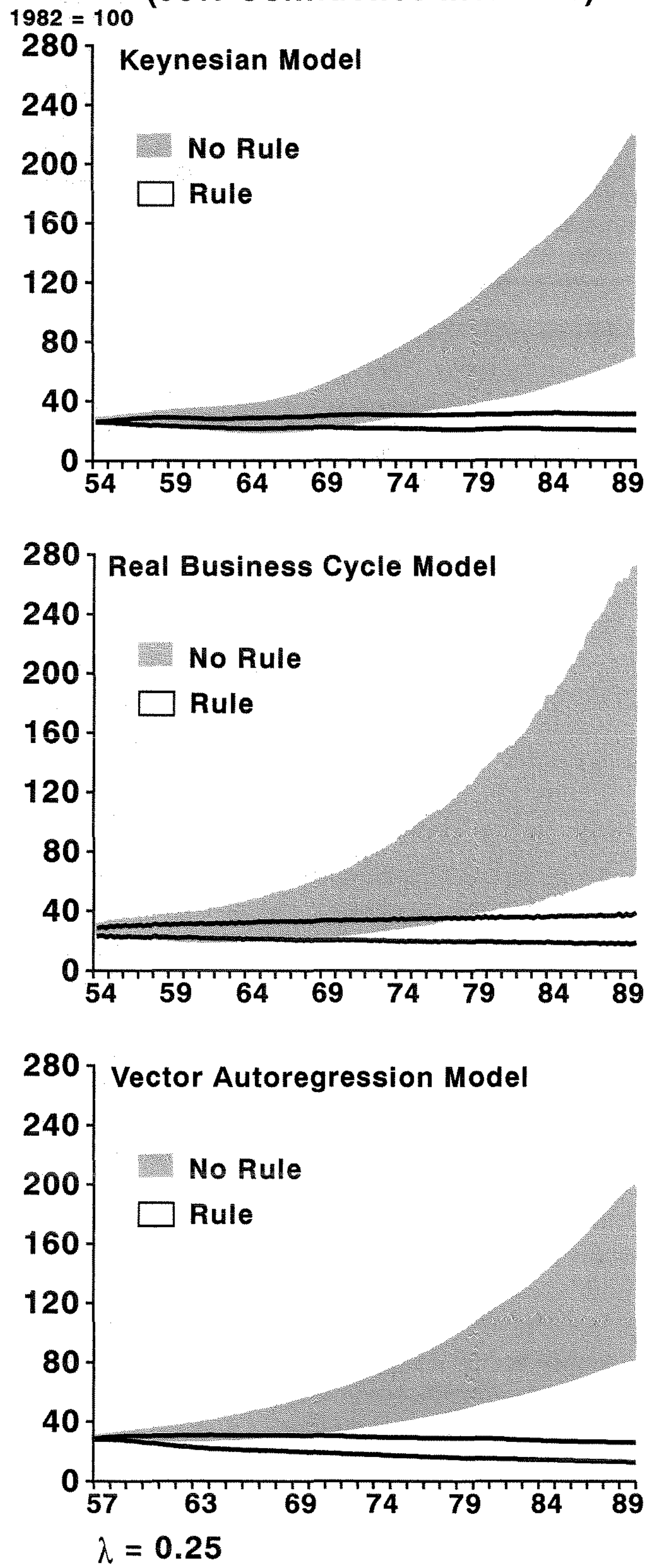


Table 2

Simulated Two-Quarter Real GNP Growth in 1989[a]

		95% Confidence Limits[b]		
Policy Rules		Keynesian	Real Business Cycle	Vector Autoregression
Nominal GNP	$\lambda = 0.25$	−10.8 to 17.5	−3.5 to 9.6	−3.2 to 11.9
	$\lambda = 0.50$	−7.3 to 13.6	−3.4 to 9.3	−7.6 to 15.7
	$\lambda = 0.75$	−6.3 to 12.7	−3.8 to 9.5	Explosive
Price Level	$\lambda = 0.25$	Explosive	−3.6 to 9.6	−3.2 to 11.4
	$\lambda = 0.75$	Explosive	−3.6 to 9.4	−13.0 to 19.5
Modified Nominal GNP	$\lambda = 0.25$	−4.4 to 9.9	−3.7 to 9.2	Explosive
	$\lambda = 0.75$	−4.8 to 10.1	−3.3 to 9.3	Explosive
No Rule (Actual Base)		−7.3 to 8.3	−3.8 to 9.6	−4.0 to 8.7
Actual Real GNP Growth			2.74	

[a]These results are referred to as counterfactual experiments in the text.
[b]Annual rates of change.

GNP. An exception to this conclusion is the modified nominal income rule in the Keynesian model. However, as noted above, this rule produces unstable results in the VAR and very wide confidence intervals for inflation under the real business cycle model.

Rules that Explicitly Attempt to Smooth Real GNP

In an attempt to find a rule that might reduce short-run real income volatility in the Keynesian model and the VAR, we experimented with a rule in which the monetary authority responded both to the level of nominal GNP (as in the nominal income rule) and to the growth rate of real GNP relative to its growth rate in the recent past.[10] In steady state, this rule would yield the same results as the nominal income rule, but it would induce a stronger response to temporary fluctuations in real GNP growth:

$$(10) \quad \Delta b_t = [\Delta y_t^f + \Delta p_t^*] - \Delta \bar{v}_t + \lambda[x_{t-1}^* - x_{t-1}] - \lambda[\Delta y_{t-1} - (\frac{1}{Q})\sum_{q=1}^{Q} \Delta y_{t-q}],$$

with Q equal to 20 quarters.

We also tried a rule that replaced the growth rates of real GNP in equation (10) with levels, so that the final term in the equation was: $-\lambda[y_{t-1} - y_{t-1}^f]$. However, we found that both rules produced somewhat *wider* fluctuations in real GNP than the simple nominal income rule in the various models. These attempts obviously do not eliminate the possibility that some other specification would reduce real GNP volatility, but at least these simple, straightforward approaches do not seem to do the job.

Disinflation Experiments

In this section, we report the results of simulating a policy rule specified so as to lower the inflation rate to zero within five years. We chose this time interval because the Neal Resolution proposes this objective for the Federal Reserve. In view of the results of the counterfactual experiments, these disinflation simulations were computed only for a nominal income rule with λ equal to 0.25.

In these simulations, the policy rule (equation (2)) was specified so that both the equilibrium growth rate of the base ($\Delta b^* = \Delta p^* + \Delta y^f$) and the targeted level of nominal income (x_{t-1}^*) allow for a gradual decline in inflation over a period of five years. This requires that Δp^* decline gradually from the actual inflation rate in 1989 to zero in 1994.Q4. From 1994.Q4 onward $\Delta p^* = 0$, and thus $\Delta b^* = \Delta y^f$. At the same time, the target level of nominal GNP (x^*_{t-1}) is set equal to the actual lagged value of nominal GNP in 1990.Q1, after which it grows at a rate that declines steadily until, after twenty quarters, it grows at Δy^f.

The results of this simulation are shown in Charts 2 through 4. Chart 2 shows the path of the inflation rate under the rule in the three alternative models, while Chart 3 shows the results for the price level. These charts suggest that in all three models, adoption of the rule would have a good chance of reducing inflation to zero within five years and of maintaining generally stable prices thereafter. The confidence bands for inflation are wide because they apply to inflation rates in individual quarters. However, the relatively narrow bands in the price level charts make it clear that average inflation over an extended period of time would be held close to zero with a high degree of confidence.[11]

Chart 4 shows the simulated two-quarter GNP growth rate in the three models. Even during the period in which the inflation rate is being brought down, there is a better than even chance that a recession can be avoided. Although the mean simulated GNP growth rate declines below the trend growth rate in the early years of the simulations, it does not become negative. Perhaps more significant is the observation that the confidence intervals on real GNP growth are no wider during the period in which inflation is coming down than they were during the historical sample period. Thus a policy of aiming for zero inflation by following a nominal income targeting policy rule would not significantly worsen the probability of the economy falling into a recession.

Chart 2
Simulated Inflation Rate
(95% Confidence Intervals)

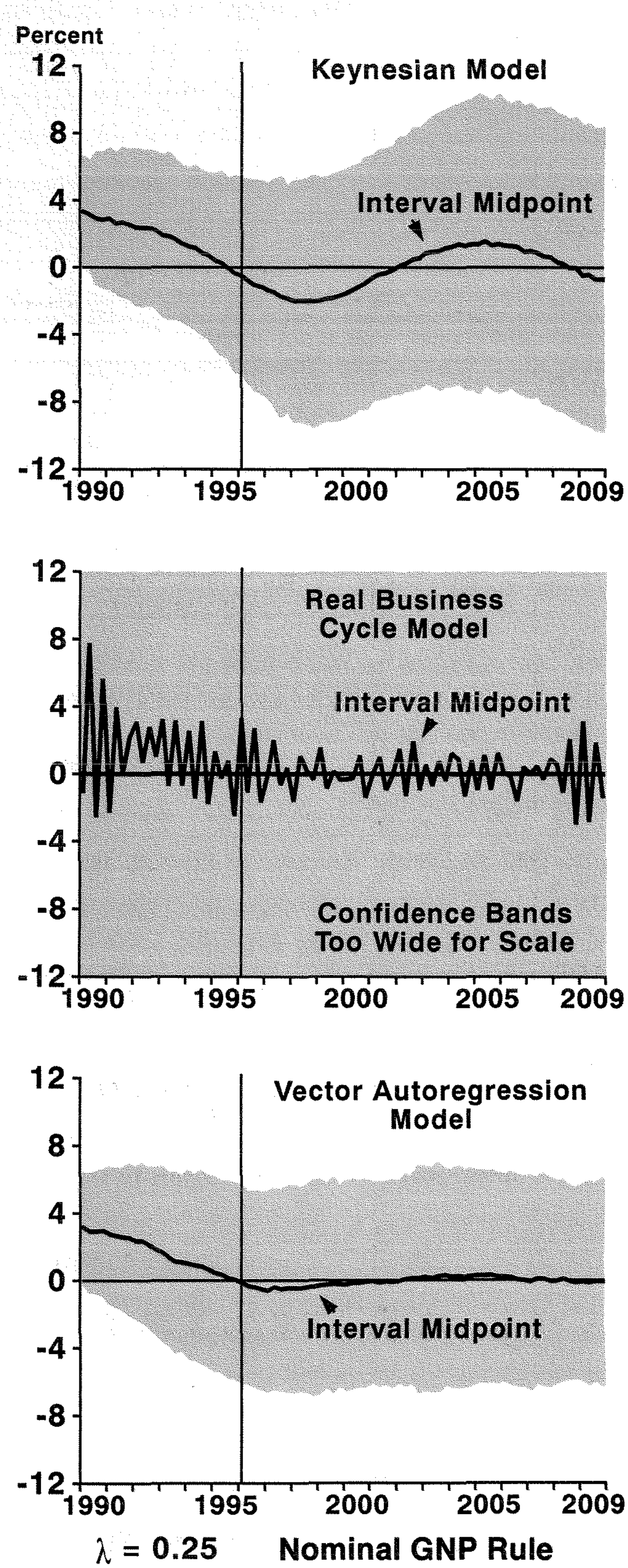
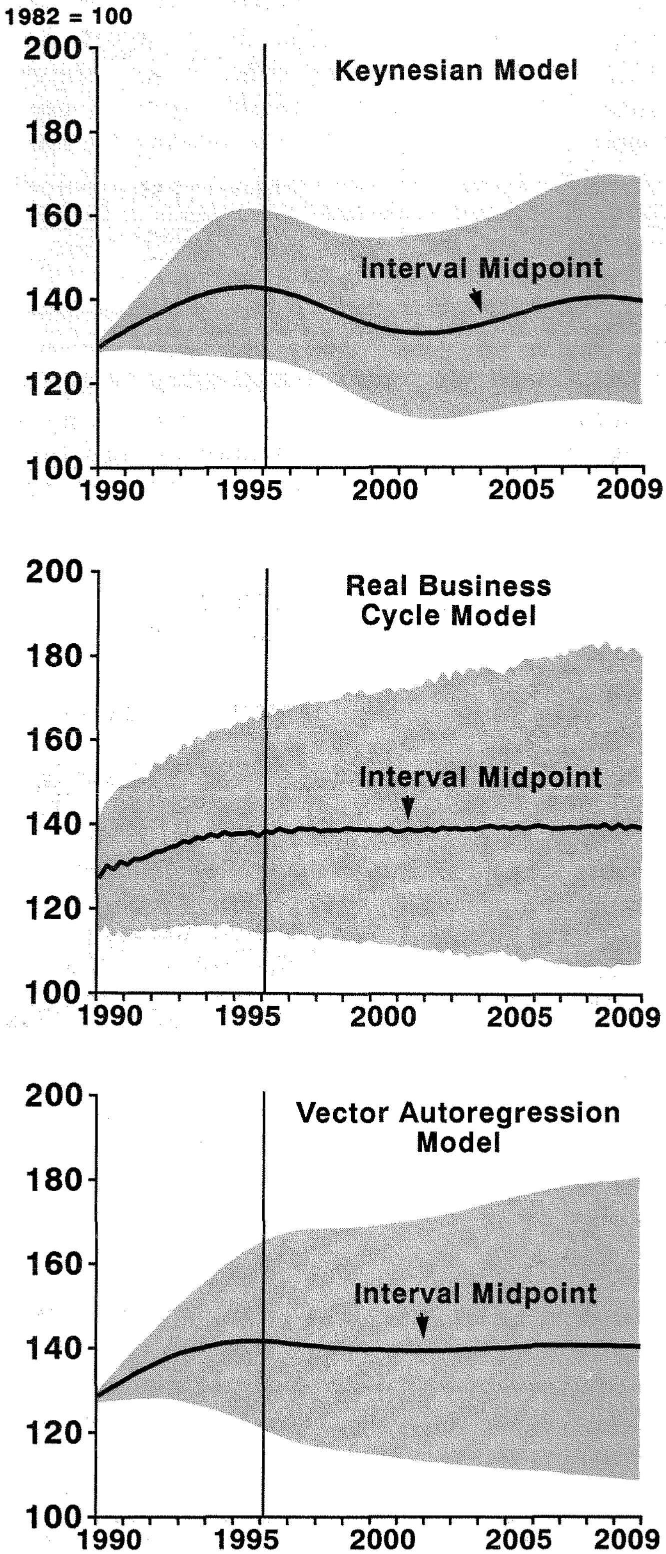
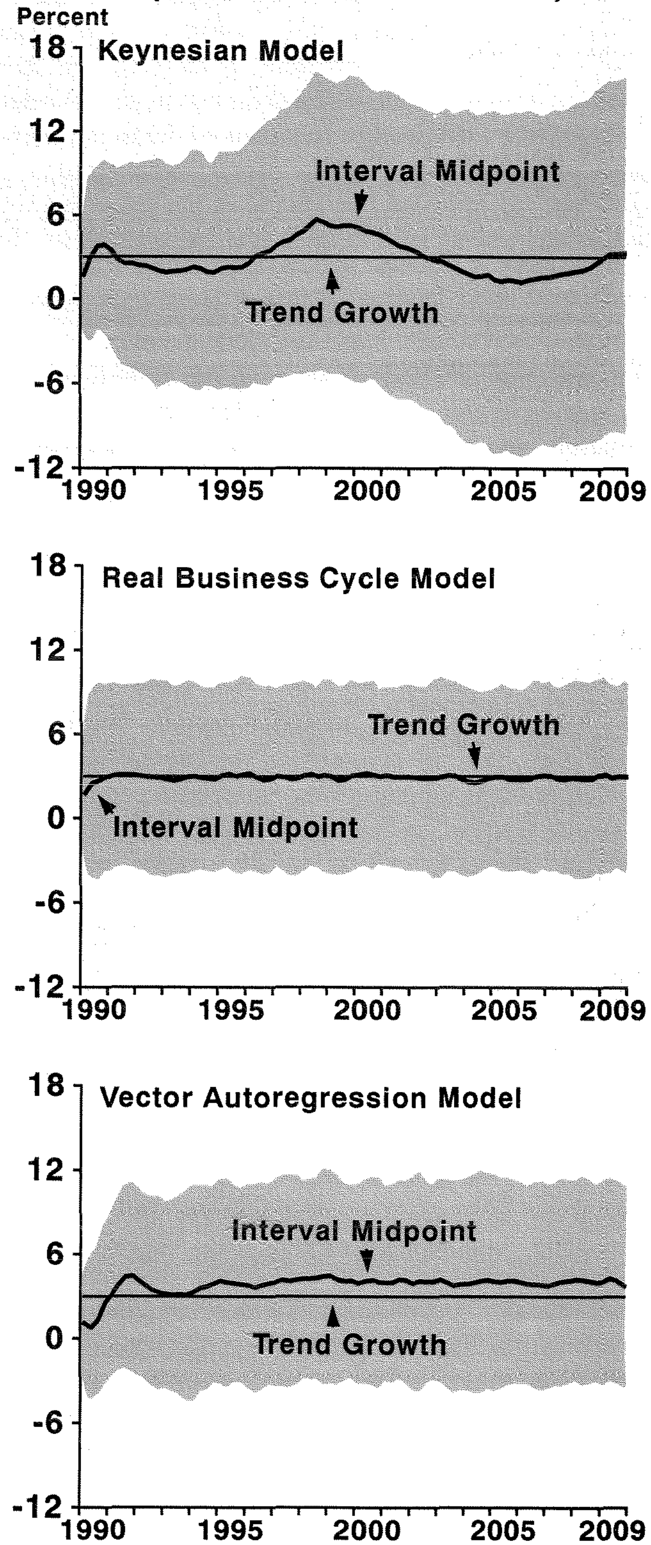


Chart 3
Simulated Price Level
(95% Confidence Intervals)



λ = 0.25 Nominal GNP Rule

Chart 4
Simulated Two-Quarter Growth of Real GNP
(95% Confidence Intervals)



λ = 0.25 Nominal GNP Rule

III. Conclusions

In this paper, we have extended the work of Bennett McCallum on the usefulness of nominal feedback rules for linking short-run monetary policy actions to the goal of achieving and maintaining price stability. Given present uncertainties about the structure of the economy, these rules are designed to be model-free; that is, the monetary authority does not need to rely on a model to implement them, and they perform well in several possible models. In addition, the rules are operational in the sense that they define movements in a variable (the monetary base) that can be controlled by the central bank.

We have examined the properties of three such rules—with short-run targets of nominal GNP, the price level, and inflation plus the GNP "gap"—in the context of three alternative views of the structure of the economy. Our tests involved numerous stochastic simulations of these models and rules. We examined the behavior of prices and real GNP during a transition from the current prevailing inflation rate to price stability, and during an extended period in which price stability is maintained.

This analysis leads us to a number of conclusions. We find that the nominal income rule is successful at maintaining price stability, in the sense that at the end of the simulations, 95 percent confidence intervals for the simulated price level are centered on the level of prices that existed at the beginning of the simulation period. Moreover, the nominal income rule provides tight confidence intervals, suggesting a high level of certainty about where prices will end up under the rule.

The price level and modified nominal income rules produce dynamic instability in some of the models tested. Only the nominal GNP rule, with relatively cautious adjustment parameters of 0.25 and 0.50, was nonexplosive in all the models. Given the uncertainty about which model is most appropriate, this would appear to be the only rule tested with sufficient robustness to be considered seriously as a target. This rule, however, does present the problem that it appears to increase real income volatility in some models. In interpreting the results for real income variability, however, it is important to bear in mind that the estimates we have obtained probably represent upper bounds on the detrimental effects of following the rules. These rules most likely would have beneficial effects on Fed credibility and would reduce uncertainty in the economy, which most likely would have beneficial effects on real income volatility (Blackburn and Christensen 1989). These beneficial effects are not captured in our simulations, and we have no way of measuring their significance.

Finally, we simulated the possible effects of moving from the present inflation rate to zero inflation in five years. We limited these experiments to the nominal income rule for reasons given above. Under all three models, this rule achieved zero inflation in five years in the sense that the confidence intervals for inflation were centered on zero. Moreover, even without beneficial credibility effects, none of the models suggested that the disinflationary process would noticeably increase the chances of a recession compared with the experience over the past 35 years under actual policy.

Thus, our results suggest that the nominal income rule could work effectively in reducing inflation from current rates to zero. Moreover, this rule would ensure price stability thereafter, although possibly at the expense of more volatility in real GNP. Whether a rule seems worth trying (ex ante) depends on how important achieving and maintaining zero inflation is to the policymaker, compared with the possible benefits of attempting to smooth real GNP. This paper has attempted to put some parameters on the nature of the tradeoff the policymaker would face in making this choice.

ENDNOTES

1. This legislation was called the "Zero-inflation" Amendment, H.R. 2795, 101st Congress, 1st session.

2. See Englander (1990) for a review of these issues and an extensive bibliography.

3. This argument assumes away the possibility that the central bank may be able to use discretion to reduce the size of fluctuations of real GNP around its full-employment level. If this were possible, and if stability had utility for the public, then there could be some positive utility from discretion in the long-run, which could offset the loss of utility from higher inflation.

4. Hence, Tobin's observation that nominal income targeting is nothing but "velocity-adjusted money targeting."

5. McCallum selected the 16-quarter average to be long enough to avoid dependence on cyclical conditions. As a consequence, the term can take account of possible changes in velocity resulting from regulatory and technological sources.

6. McCallum also examines the properties of a rational expectations inflation surprise model (Lucas 1973). We decided not to pursue this approach because it no longer receives much support from macroeconomists.

7. In the Appendix, we reproduce some of McCallum's simulation results. Following his approach, in this table we used only one set of shocks, equal to the actual historical errors in the estimated equations. Our results are similar to his.

8. The simulation of the VAR under the nominal income rule produced a gradual decline in the price level. At the same time, the model predicts that real GNP would have risen more rapidly than actually occurred historically. This result implies that to produce zero inflation, the rule should have specified a faster steady-state growth rate of the base. It appears that the VAR model embodies an inverse correlation between the inflation rate and the real GNP growth rate. This correlation also is found in Lebow, Roberts, and Stockton (1990) and Selody (1990). Thus if the growth rate of the base is reduced to hold down inflation, the trend growth rate of real GNP is higher. One of the main arguments in favor of price stability is that it would boost real growth by facilitating long-range planning and eliminating the need for economic agents to waste resources in efforts to avoid the effects of inflation. The VAR appears to be consistent with this view. By experimentation, we found that if the base growth rate was set to produce zero inflation, the trend GNP growth rate was 4 percent, rather than the actual trend rate of 2¾ percent over the historical sample.

9. Simulations also were computed with an inflation rule, but this procedure produced instability in all models and so was abandoned.

10. Recall that policy does not affect real GNP in the real business cycle model.

11. Prices are more volatile in the real business cycle model than in the other models, because holding nominal income stable implies that independent fluctuations in real GNP are mirrored in opposite fluctuations in prices.

APPENDIX

Regression Results

1954.1—1989.4

The variables in the regressions below are defined as follows:

b = log of monetary base (adjusted for reserve requirement changes)
g = log of high-employment government expenditures
p = log of GNP deflator
i = log of 3-month Treasury bill rate
y = log of real GNP
y^f = log of real GNP trend
T = time trend

Keynesian Model

Aggregate Demand:

$$\text{(A1)}\ \Delta y_t = \underset{(4.64)}{0.0044} + \underset{(3.29)}{0.26}\ \Delta y_{t-1} + \underset{(2.17)}{0.25}\ (\Delta b_t - \Delta p_t) + \underset{(1.51)}{0.18}\ (\Delta b_{t-1} - \Delta p_{t-1}) + \underset{(2.20)}{0.091}\ \Delta g_t - \underset{(-2.20)}{0.091}\ \Delta g_{t-1}$$

$\bar{R}^2$ = 0.19
SEE = 0.0091
Q = 26.08
D.F. = 139

Aggregate Supply:

$$\text{(A2)}\ \Delta p_t = \underset{(2.71)}{0.026}\ (y_t - y_t^f) + \underset{(4.22)}{0.35}\ \Delta p_{t-1} + \underset{(2.66)}{0.23}\ \Delta p_{t-2} + \underset{(2.46)}{0.23}\ \Delta p_{t-3} + \underset{(2.38)}{0.20}\ \Delta p_{t-4}$$

$\bar{R}^2$ = 0.62
SEE = 0.0041
Q = 26.97
D.F. = 140

$$\text{(A3)}\ y_t^f = \underset{(855.16)}{7.05} + \underset{+\ (99.71)}{0.007557}\ T_t$$

$\bar{R}^2$ = 0.99
SEE = 0.038
Q = 982.64
D.F. = 142

Real Business Cycle Model

Aggregate Demand

$$\text{(A4)}\ \Delta p_t = 0.017 - 3.94\Delta y_t + 1.01\Delta y_{t-1} + \Delta b_t + 0.72\Delta b_{t-1} - 0.72\Delta p_{t-1} + 0.36\Delta g_t - 0.36\Delta g_{t-1}$$

Aggregate Supply:

$$\text{(A5)}\ \Delta y_t = \underset{(4.59)}{0.0051} + \underset{(3.60)}{0.30}\ \Delta y_{t-1} + \underset{(1.65)}{0.14}\ \Delta y_{t-2} - \underset{(-1.54)}{0.13}\ \Delta y_{t-3}$$

$\bar{R}^2$ = 0.11
SEE = 0.0093
Q = 25.23
D.F. = 140

Vector Autoregression

Marginal Significance Levels

	Dependent Variables[a]			
	Δy	Δp	R	Δb
Δy	0.300000	0.700000	0.005000	0.018000
Δp	0.300000	0.000015	0.091000	0.180000
R	0.000016	0.035000	0.000000	0.000000
Δb	0.007800	0.008000	0.051000	0.000000
$\bar{R}^2$	0.300000	0.673000	0.930000	0.710000
SEE	0.008400	0.003900	0.950000	0.003700
Q	23.920000	38.910000	34.990000	29.880000
D.F.	120	124	119	121

[a]Lags chosen by Final Prediction Error procedure (Judge, et al. 1985).

Simulations of Alternative Target Variables[a]

1954.1—1989.4

		RMSE Values		
Targets		**Keynesian**	**Real Business Cycle**	**Vector Autoregression**
Nominal GNP	$\lambda = 0.25$[b]	0.0268	0.0167	0.0237
	$\lambda = 0.75$	0.0171	0.0115	Explosive
Price Level	$\lambda = 0.25$[b]	Explosive	0.0161	0.0293
	$\lambda = 0.75$	Explosive	0.0080	0.0490
Modified	$\lambda = 0.25$	0.0279	0.0317	Explosive
Nominal GNP	$\lambda = 0.75$	0.0196	0.0240	Explosive

[a]Shocks equal residuals in estimated model equations.
[b]See Tables 1 and 2 in McCallum (1988b).

REFERENCES

Barro, Robert J. 1986. "Recent Developments in the Theory of Rules Versus Discretion." *The Economic Journal* Supplement, pp. 23-37.

________, and David B. Gordon. 1983. "A Positive Theory of Monetary Policy in a Natural Rate Model." *Journal of Political Economy* pp. 589-610.

Blackburn, Keith, and Michael Christensen. 1989. "Monetary Policy and Policy Credibility: Theories and Evidence." *Journal of Economic Literature* (March) pp. 1-45.

Englander, A. Steven. 1990. "Optimal Monetary Policy Design: Rules versus Discretion Again." In *Intermediate Targets and Indicators of Monetary Policy*. Federal Reserve Bank of New York.

Evans, George W. 1989. "Output and Unemployment Dynamics in the United States: 1950-1985." *Journal of Applied Econometrics* 4, pp. 213-238.

Friedman, Milton. 1960. *A Program for Monetary Stability*. New York: Fordham University Press.

Greenspan, Alan. 1989. "A Statement before the Subcommittee on Domestic Monetary Policy of the Committee on Banking, Finance and Urban Affairs, U.S. House of Representatives, October 25, 1989." *Federal Reserve Bulletin* (December) pp. 795-803.

Hall, Robert E. 1983. "Macroeconomic Policy Under Structural Change." In *Industrial Change and Public Policy*, pp. 85-111. Federal Reserve Bank of Kansas City.

Haraf, William S. 1986. "Monetary Velocity and Monetary Rules." *Cato Journal* (Fall) pp. 641-662.

Heller, Robert H. 1988. "The Making of U.S. Monetary Policy." Paper presented at Seminar for Economic Policy, April 27. The University of Cologne, West Germany.

Hoskins, W. Lee. 1989. "Monetary Policy, Information, and Price Stability." Federal Reserve Bank of Cleveland *Economic Commentary* (February).

Judge, C.G., W.E. Griffiths, R.C. Hill, H. Lutkepohl, and T.C. Lee. 1985. *The Theory and Practice of Econometrics*. New York: John Wiley.

Kydland, Finn E., and Edward C. Prescott. 1977. "Rules Rather Than Discretion: Time Inconsistency of Optimal Plans." *Journal of Political Economy* pp. 473-491.

Lebow, David E., John M. Roberts and David J. Stockton. 1990. "Economic Performance under Price Stability." Unpublished paper, Board of Governors of the Federal Reserve System (December).

Lucas, Robert E. 1973. "Some International Evidence on Output-Inflation Trade-offs. *American Economic Review* pp. 326-334.

Mankiw, N. Gregory. 1989. "Real Business Cycles: A New Keynesian Perspective." *The Journal of Economic Perspectives* (Spring) pp. 79-90.

________. 1990. "A Quick Refresher Course in Macroeconomics." *Journal of Economic Literature* (December) pp. 1645-1660.

McCallum, Bennett T. 1988a. "Robustness Properties of a Rule for Monetary Policy." *Carnegie-Rochester Conference Series on Public Policy* 29, pp. 173-204.

________. 1988b. "Targets, Indicators, and Instruments of Monetary Policy." In *Monetary Policy in an Era of Change*. Washington, D.C.: American Enterprise Institute.

Meltzer, Allan. 1984. "Credibility and Monetary Policy." In *Price Stability and Public Policy*, pp. 105-128. Federal Reserve Bank of Kansas City.

Parry, Robert T. 1990. "Price Level Stability." Federal Reserve Bank of San Francisco *Weekly Letter* (March 2).

Selody, Jack C. 1990. "The Benefits and Costs of Price Stability: An Empirical Assessment." Unpublished paper, Bank of Canada (December).

Simpson, Thomas C. 1984. "Changes in the Financial System: Implications for Monetary Policy." *Brookings Papers on Economic Activity* 1, pp. 249-272.

Taylor, John B. 1984. "Recent Changes in Macro Policy and Its Effects: Some Time Series Evidence." *American Economic Review* Papers and Proceedings, pp. 206-210.

________. 1985. "What Would Nominal GNP Targeting Do to the Business Cycle?" *Carnegie-Rochester Conference Series on Public Policy* 22, pp. 61-84.

Tobin, James 1980. "Stabilization Policy Ten Years After." *Brookings Papers on Economic Activity* 1, pp. 19-49.